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"Extreme Foundations" for Peat Deposits: Conceptual Model, Creative Thinking and Learning Process

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ABSTRACT

As engineering is essentially an application of science and mathematics to resolve real-life, practical problems, incorporation of actual field encounters or case histories in the teaching process can facilitate better understanding among students by providing a link between the theories and the applied solutions. It is the same for geo-engineering courses, like Advanced Foundation Engineering. By introducing the study of a relevant existing case in the course, the gap between theories and field applications can be effectively bridged. It is therefore no wonder that recent years have seen increased emphasis on problem-based learning in the delivery of engineering courses. In this paper, the implementation of a group project in the final year Advanced Foundation Engineering course in the form of a case study is discussed. Set against the background of challenging foundation issues on deep peat deposit at Sibu, Sarawak state of East Malaysia, students were required to examine the underlying problems and to propose an effective solution. Individual groups of 4-5 students exercised critical thinking in systematically analyzing the causes of foundation failures in the area and formulating suitable solutions based on lectures, extra reading and talking to the experts. Weekly discourse was held with the lecturer throughout the 12-week endeavour to ensure satisfactory work progress as well as to provide guidance where necessary. At the end of the project, each group constructed a scaled model to demonstrate the conceptual model of their respective foundation design and solution to the problematic soil. Documentation included the Project Folder, which chronicled the development of the conceptual model and design (i.e. project management); and the Technical Report, which elaborated and explained the creative work of the students (i.e. technical writing). In a nutshell, the embedded case study approach enlivened the learning process of an otherwise 'dreary' subject, and helped to enhance the students' soft skills often overlooked in the delivery of geo-engineering courses.

INTRODUCTION

In the teaching of geo-engineering courses, lecturing and demonstrating solutions to problems are no longer seen as an effective delivery method. This traditional approach has in fact become the 'obvious culprit' commonly blamed for engineering graduates incapable of solving real life problems at excel at resolving textbook ones (e.g. Perkins & Salomon, 1989; Mayer, 1996). In order to mimic human's natural learning process, i.e. encounter a problem, assess the circumstances and situation, then formulate an effective solution, problem-based learning (PBL) was eventually developed in the 50's and widely implemented in the academia today.

It is perhaps not surprising that PBL originated in medical education (Hmelo-Silver, 2004; Torp & Sage, 2002; Barrows, 2000), where clinical competency requires students to possess the fundamental knowledge and to apply the knowledge in the right context with minimal room for mistakes (i.e. problem-solving skills). PBL forms part of the instructional approach attributed to Dewey (1938), who emphasized on the importance of practical experience in learning. It underlines that with greater student's engagement in learning, with more self-reliant guidance or directives as well as higher levels of satisfaction as a reward. PBL is also claimed to enhance clinical, and by extrapolation, practical knowledge, practical reasoning skills, learning motivation and learning autonomy (Thomas, 1997). This is perhaps why PBL is so popularly adopted worldwide in engineering education these days.

A 100 % implementation of PBL in the delivery of a geo-engineering course may prove too drastic a change from the traditional passive learning environment in most institutions of higher learning. As such, it is usually incorporated as part of a course, such as an embedded project, with suitable themes and background related to the course. Real life problems are preferable to provide exposure to students, encouraging them to identify the link between knowledge gained in lectures and the applications of it. The integration of knowledge learned in lectures with knowledge learned in practice is a significant matter, though they remain separate, discrete, non-overlapping and inert respectively (Leinhardt et al., 1995). By transforming the two categories of knowledge into forms which are inter-related, it could contribute towards better integration of professional knowledge (e.g. engineering) and developing greater practical skills (e.g. problem-solving).

The incorporation of a problem-based project in a course introduces elements not unlike that of cooperative enterprise, especially when the students conduct the projects in groups. With different backgrounds and abilities but generally similar level of knowledge of the course, each member of the group is assigned different responsibilities and tasks. Hence the success of a project no longer depends on the technical expertise and understanding alone, but perhaps more so on the essence of successful teamwork (Rugarcia et al., 2000). Sawyer (2007) elaborated on how working in a team encourages collaborative creativity, which often triggers the free-wheeling nature of innovation. This suggests additional benefits for the students carrying out the projects in groups and not individually.

Due to time constraint in typical 14-week course duration, a group approach also tends to shed some pressure off the students in completing the project. The active and collaborative learning process allows students to learn from their peers and share their own thoughts or ideas via critical thinking. With tasks assigned to individual members of the group, each member has the opportunity and responsibility to embark on a uniquely independent yet dependent working environment, where their joint effort will finally lead to realistic products, designs and presentations (Carbonell, 2001; Johanessen et al., 2001; Simplicio, 2000). In addition, the working group enables peer-tutoring of the weaker students, further improving understanding of the course contents in time. Mutual interests among peers breaks down the communication barrier and creates common platforms for the students to communicate, discuss intellectually, use relevant analogy and examples, with the appropriate level of detail and language found only among peers (Roscoe &d Chi, 2007).

PROJECT: CONCEPTUALIZING CREATIVITY

At the beginning of the 14-week semester, 22 students of the elective Advanced Foundation Engineering course were assigned a group project. The students decided to form groups of 4-5 students in a total of 5 groups. Following is the adapted project brief as received by the students.

> Sarawak has approximately 1.7 million ha of tropical peat that covers 13 % of the total land area (12.4 million ha). It is the largest area of peat land in Malaysia, with average depths reaching 2.5 m, and constitutes nearly 63 % of the total peat land of the country (Fig. 1). Sibu is located at the confluence of Batang Rajang and Batang Igan. The town and it's surroundings are overlain with substantial formations of peat soils, almost unrivalled when compared to other parts of Malaysia. The peat formations in some parts of Sibu are well over 10 m deep. Fig. 2 shows a historical developmet of Sibu town with relevance to the ground subsidence problems.

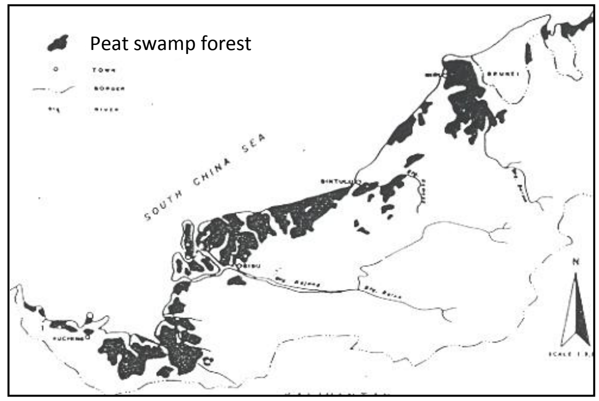

Fig. 1. Peat swamps in Sarawak (Singh et al., 1997).

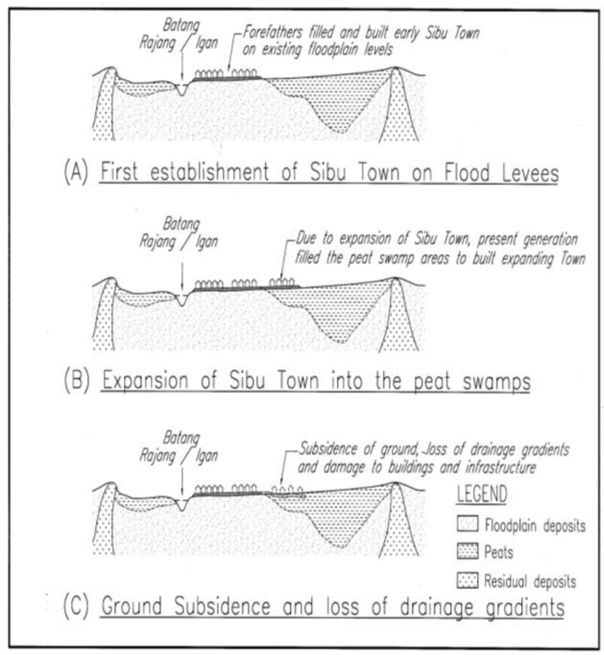

Fig. 2. Historical development of Sibu and the related ground subsidence problem (Tang, 2009).

> The problems in designing and construction of embankment over very soft compressible peat and organic soils in Sibu arise due to the high compressibility (comprssion index, c_c=1.05-1.64), low shear strength (undrained shear strength, $c_u \leq 10$ kPa), high natural moisture content and high ground water level (near to ground surface). Land subsidence is a serious problem in

Sibu, with frequent refilling and repairing being carried out to reinstate structures, platforms and infrastructure.

The other related engineering problems are upthrusting of drains, side flows, severe rapid pavement distress, road subsidence below normal flood level, vibration damage from construction / logging machineries and heavy traffic. Some severely damaged infrastructure is caotured in Fig. 3.

Fig. 3. The sinking of Sibu: (clockwise) multi-storey buildings losing the ground floors- subsidence, a 'dancing' house due to non-uniform settlement, road and drain at the same level- excessive subsidence, a 'hanging' school with significant ground loss.

Due to the problems highlighted above, construction work in Sibu has to accommodate and adapt to the following conditions: ground improvement works prior to road construction for adequate foundation support, measures to avoid excessive differential and long term creep settlement, as well as effective land drainage to prevent flooding.

THE TASKS AND METHODOLOGY

The project brief informed the students that they were to play the role of a geotechnical consulting firm, engaged to advise the Public Works Department of Sibu on an effective foundation system to cater for development over the widespread and deep peat deposit. The specific tasks for each groups are given below:

i. To design a foundation system for ANY of the problems (e.g. road embankment, buildings, etc.).
ii. To support the proposal with substantial reasoning based on technical facts and arguments.
iii. To build a scaled model of the proposed solution with dimensions: 30 cm x 30 cm, NOT exceeding 50 cm high.
iv. To explain and 'sell' the design in a presentation session.
v. To communicate details of the design in a concise technical report (note: guided details were included in the brief to assist the students in report-writing).

Objectives of the project were also clearly stated in the brief to ensure students understand the purpose of the exercise:

- To identify challenges encountered in a problematic peat soil area.
- To formulate solutions through an effective foundation design, with creativity and innovation.
- To exercise team work and coordination in carrying out a small-scale research project within a given time frame.

Although the embedded project aimed to motivate active learning among the students, time constraint, academic workload from other courses as well as the Final Year Project could adversely affect the students' motivation to participate in the group work voluntarily. A step-by-step methodology was included in the project brief, partly to assist the students in starting the ball rolling, and partly to provide some form of guidance in a largely student- or learner-centred learning process. The methodology outline is shown below:

1. Start a Proposal Development Folder: records of group discussions, progress and other information.
2. Identify the problem to be solved.
3. Read up on the geotechnical and foundation engineering methods applicable- background study.
4. Brainstorm and innovate on the various methods / designs.
5. Refine the method / design chosen.
6. Estimate the actual costs involved- materials, labour, machinery, etc.
7. Build the model to scale.
8. Prepare the technical report and presentation materials (e.g. poster).
9. Submission: model, technical report and CD containing all the data and information (note: data storage in the CD was meant for record purposes and as reference in the project evaluation).

ASSESSMENT

A brief guide on the presentation, which was conducted in the form of a miniature exhibition with assessment by a pair of external judges is as follows:

Each group will present their solutions to a panel of judges in an exhibition at the end of the semester.

- Describe and explain the design / method.

- Highlight the creativity, innovation and cost-effectiveness of your design / method.
- Justify why the Public Works Department of Sibu (as the Client) should adopt your design / method- unique, sustainable, 'green', etc.

EDUCATIONAL OBJECTIVES AND OUTCOMES: EVALUATION OF LEARNING PROCESS

As the course itself is part of a larger engineering programme, the Programme Learning Outcomes (PLOs) are naturally in line and derived from the Programme Educational Objectives (PEOs). The PLOs are expected to be attained immediately upon completion of the programme, while the PEOs are measured on a longer term basis, i.e. 4-5 years after the students graduate and start a career. Andrich (2002) pointed out that modern educational reforms have shared a pervasive common feature in the focus on educational outcomes. He further explained that educational outcomes at the highest level governs and generate the inter-related components, and students must be helped to achieve these outcomes at the most significant levels possible. The project was intended for that.

The level of achievement of these stipulated outcomes and objectives can be projected from the students' input based on this embedded project exercise. An exit survey was conducted at the end of the semester to gauge the effectiveness of PBL's implementation through the project. Presented in Tables 1 and 2 are the adapted PEOs and PLOs referred to in the present study, with relevance to the embedded project.

Table 1. Programme Educational Objectives (PEOs)

PEO1	Knowledgeable in relevant civil engineering disciplines in-line with the industrial requirements.
PEO2	Technically competent in solving problems through critical and analytical approaches with sound facts and ideas.
PEO3	Effective in communication with strong leadership quality.
PEO4	Capable of addressing engineering issues and able to conduct professional responsibilities ethically.

Table 2. Programme Learning Outcomes (PLOs)

PLO1	Apply lessons learnt during lectures in practical applications.
PLO2	Acquire additional ICT skills and knowledge by doing the project.
PLO3	Analyze, design and understand the process of construction in Geotechnical Engineering.
PLO4	Identify problems and formulate systematic solutions in the project.
PLO5	Apply scientific methods for a project of R&D (research and development) nature.
PLO6	Recognize and understand the importance of sustainable development and Occupational Safety and Health (OSH).
PLO7	Recognize the roles and ethics of a professional engineer in fulfilling social, cultural and environmental obligations.
PLO8	Communicate ideas effectively through oral, written and ICT applications.
PLO9	Display leadership, entrepreneurship and team working skills effectively.
PLO10	Recognize the need for and the ability to engage in lifelong learning.

DEVELOPMENT OF EMBEDDED SOFT SKILLS

Increasing market competition and technology advancement, together with the advent of international boundaries collapsing into blurred global networks, have markedly increased the industrial requirement of engineering graduates. The skill sets expected of an engineer no longer include mere technical knowhow, but also professional skills like communication, teamwork, leadership, business knowledge, entrepreneurship and project management (Sanchez et al., 2009; Moon et al., 2007). These 'soft' or 'humanistic' skills are also evaluated as part of the exit survey (Table 3).

Table 3. Humanistic Skills (HSs)

HS1	Communication skills.
HS2	Critical thinking and problem-solving skills.
HS3	Team-working skills.
HS4	Continuous learning and information management skills.
HS5	Entrepreneurship skills.
HS6	Ethics and professionalism.
HS7	Leadership.

PROPOSED FOUNDATION SYSTEMS: DISPLAY OF CREATIVITY AND INNOVATION

The students' proposed solutions for the foundation problems were an excellent piece of evidence that creativity and innovation took precedent over rigid technical conventions throughout the project execution (Fig. 4). They were able to demonstrate engineering solutions which ensure continued or increased productivity, potentially spurs economic growth and social well-being, all clear signs of the creative problem-solving process (Ott & Pozzi, 2010). A brief description of each of the proposed solution is included in the following.

1. Mat foundation incorporated with short, hollow piles: integrated with a moat-like perimeter drainage system to control the water table, hence keeping heaving and subsidence in check.
2. Floating timber foundation: reusing the trees cut

down to make way for a new road; arranged in a criss-cross pattern for enhanced stability and bearing capacity; interlocked with granular backfill; sustainable approach with waste material reuse.

3. 'TimberMAT': a combination of geotextile as separator, *bakau* or mangrove trunks as an interlocked mat, backfilled with lightweight geomaterial; semi-floating (compensated foundation); smart use of a farmable, robust wood grown in natural swamps.
4. Lightweight foundation with expanded polystyrene (EPS): incorporated with sub-surface drainage to control water table; proposed protective coating of EPS from chemical attack in harsh, acidic peat environment
5. 'Bite' foundation: cylindrical steel pipes with protruding spikes for better grip with fibrous matter of peat; spikes are retractable during installation (minimize resistance against penetration)

Fig. 4. The students in action during the mini exhibition.

FINDINGS FROM EXIT SURVEY

As the questions in the exit survey were framed in the context of the PEOs, PLOs and HSs, with relevance to the project itself, it actually reflects, in extension, the project's impact on the overall achievement of the programme's aspired outcomes. The sample is admittedly small, as limited by the number of students taking the elective course. Nonetheless it does represent a small community of students engaged in a collaborative manner while completing the project. In the survey, students were asked to rate their perception of the impact level of each component, on a simplified scale of low, moderate of high. The survey was intentionally kept simple to extract the first and intuitive responses of the students, hence capturing what they really thought about how the project affected their learning of the course specifically and the programme in general.

Fig. 5 summarizes the overall rating of the parameters examined. It interesting to note from the pie charts for PEO and PLO that the percentages for each level were very similar. This indicates a distinct correlation between the two, where the PLOs were essentially in support of the overall expected outcomes of the programmes itself. There is an almost 100 % agreement (with an approximate ratio of 1.5 times more 'highs' than 'moderates') that the project facilitated knowledge-building, problem-solving skills, enhancement of communication skills, leadership attributes and real life engineering professionalism. It follows that the students saw their soft skills considerably improved too, as shown by the HS's chart. The 1-2 % of 'low' impact level was probably affected by individual student's interest and commitment to the project, or an unclear understanding of the purpose of the embedded project itself.

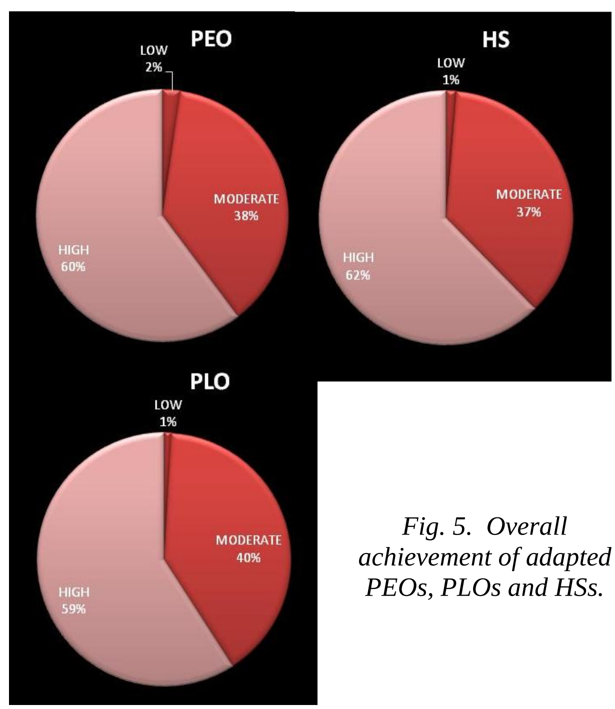

Fig. 5. Overall achievement of adapted PEOs, PLOs and HSs.

To examine the adapted PEO-PLO and HS relationship more thoroughly, a spatial diagram was plotted in Fig. 6. The individual data point represents a single response in the particular sub-component of PLO, and the shaded areas encapsulate the data for each component of PEO, PLO or HS. Only the PLO data point was included in the plot because it consists of the most sub-components, of which any scatter or anomalies in the plot will be apparent. Also, it avoids clutter in the diagram with too many overlapping data.

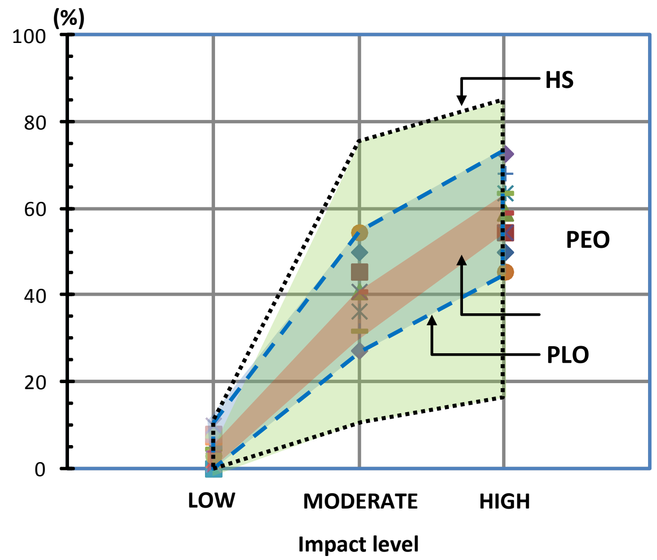

Fig. 6. Spatial diagram PEO-PLO-HS relationship.

Referring to Fig. 6, the dashed boundary encompasses the PLO achievement, while the smaller strip within represents the data distribution of the PEO component. As discussed earlier, the PEO-PLO achievement is parallel and closely related. The overall incremental pattern of the plot is also a positive sign of the benefits of embedded projects in this particular engineering course. To a lesser extent it actually helps to rule out the possible bias caused by nonchalant respondents. As in all surveys, especially if the population sampled is not large, the resulting analysis may be significantly affected by such non-representative responses.

The larger area in the plot shows the scatter in the HS data. This could be indicative of the difficulty in gauging the development of soft skills in a team working environment. Due to inherent personal characteristics and attributes, each student naturally had different reactions and response in conducting the project. For instance, a student of more reserved and taciturn nature may find working in a group daunting, especially when he or she is repeatedly persuaded to demonstrate greater participation and commitment through verbal interaction. While having a quiet temperament does not necessarily mean lack of confidence, such pressures from other more expressive group members could impede the development of self worth in public engagement.

Table 4. Achievement of HS (in terms of number of respondents)

HS	Impact Level		
	LOW	MODERATE	HIGH
1	1	9	12
2	0	10	12
3	0	3	19
4	0	4	18
5	1	17	4
6	0	7	15
7	0	6	16

In spite of the encouraging results so far, an embedded project does not necessarily contribute to all the intended outcomes. Table 4 shows the number of respondents to each sub-component of HS (see Table 3 too). It is obvious that the students did not consider their entrepreneur skills (HS5) greatly improved by carrying out the project. Perhaps a market needs and cost analysis could be incorporated in future projects for the purpose. On the other hand, the significant 'high' responses for HS3 and HS4 give some insights to the effect of the project implementation, i.e. (1) team working; (2) the realization that the engineering profession requires continuous acquisition of new knowledge and experience; (3) understanding the importance of good record keeping and information management.

CONCLUSIONS

The embedded problem-based project in the course of Advanced Foundation Engineering has shown encouraging results in terms of projected PEO-PLO and HS achievements. Analysis of results from the exit survey displayed the students' ability to work collaboratively in groups with moderate facilitation, not supervision, on the lecturer's part. The foundation designs embodied logical and critical thinking in the conceptualization of a real life engineering problem and formulation of an innovative solution. The learning process was markedly enlivened and enriched, despite the constraint of time and resources. Lastly, analytical results of the exit survey show that there remains room for improvement in the project design, to further optimize the advantages and benefits for the students.

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